DOCUMENT RESUME

ED 263 020 SE 046 247

AUTHOR Byrne, Michael
TITLE Zinc and You.
INSTITUTION Royal Society of Chemistry (Scotland). Education Div.
SPONS AGENCY Royal Society of Chemistry (Scotland). Education Appeal Fund.; Scottish Curriculum Development Service (Scotland). Education for the Industrial Society Group.
PUB DATE [84]
NOTE 42p.; One of a series entitled "Interactive Teaching Material for Schools and Colleges: Chemistry Packages for Sixth Formers." For the other documents in the series, see SE 046 246-251.
AVAILABLE FROM Scottish Council for Educational Technology, Victoria Crescent Road, Dowanhill, Glasgow G12 9JN, Scotland (1 pound plus postage).
PUB TYPE Guides - Classroom Use - Guides (For Teachers) (052)

EDRS PRICE MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS *Chemistry; *Metals; *Science Activities; Science Curriculum; Science Education; *Science Instruction; Secondary Education; *Secondary School Science; Teaching Methods; Units of Study
IDENTIFIERS *Scotland; *Zinc

ABSTRACT

This unit is one of a group of units written to fit the Certificate of Sixth Year Studies (CSYS) chemistry course, but it could also be used in most Sixth Form courses. It includes: (1) background notes for teachers including answers and a discussion guide; (2) a student copy of objectives and discussion suggestions; (3) background information for students, a set of problems, and data sheets (reference diagram and charts); and (4) summary sheets describing uses of zinc and processes of zinc extraction. The unit was developed for use in an interactive way to give students experience in making decisions based on knowledge of chemistry and other disciplines so that they may understand that chemical industry decisions are often of necessity multi-disciplinary. (DH)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

U.S. DEPARTMENT OF EDUCATION
NATIONAL INSTITUTE OF EDUCATION
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

☑ This document has been reproduced as received from the person or organization originating it.

☐ Minor changes have been made to improve reproduction quality.

• Points of view or opinions stated in this document do not necessarily represent official NIE position or policy.

Royal Society of Chemistry Education Division

SE 041 347 ED 263 020

ZINC AND YOU

"PERMISSION TO REPRODUCE THIS MATERIAL IN MICROFICHE ONLY HAS BEEN GRANTED BY

Royal Society of Chemistry

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

ZINC AND YOU

This unit is one of a group of units written to fit the Certificate of Sixth Year Studies course but could certainly find a place in most Sixth Form courses.

The series has been written by a group of teachers, college lecturers, university lecturers and industrialists.

It has been supported financially by the Education Appeal Fund of the Royal Society of Chemistry and the Education for the Industrial Society Group of the Scottish Curriculum Development Service and has received the approval of the Chemistry Panel of the Scottish Examination Board.

It is hoped that this will be used in an interactive way to give pupils the experience of making decisions for themselves on the basis of their chemical knowledge and the knowledge of other disciplines, so that they may truly see that the decisions of chemical industry are of necessity - multi disciplinary.

We realise that this unit will not be perfect and we would welcome helpful criticism so that later editions can be improved.

Dr. A.H. Johnstone
General Editor.

The writer of this unit was -

Mr. Michael Byrne, Newcastle-upon-Tyne Polytechnic based upon an original version by Dr. B.J. Levine, University of New England, Australia.

We also acknowledge the support and advice of Mr. J.H. Ashton, Imperial Smelting Processes Ltd., Avonmouth.

COPYRIGHT. The copyright for this unit rests with the Royal Society of Chemistry. Individual teachers are welcome to copy the material without reference to the Society, strictly for use with their own classes.

ZINC AND YOU
Teachers Guide

T.1. TEACHER'S GUIDE

1. Aim of the Exercise

The exercise is designed to help pupils to learn more about zinc and how to apply their knowledge of chemistry to a real industrial situation. It is best used with a group of 4 - 7 pupils but it can be used with both smaller and larger pupil groups.

2. Contents of the Package

(a) Teacher's Material (blue sheets)

- T.1. Teacher's Guide
- T.2. List of Objectives (teacher's copy)
- T.3. Extracting Zinc from its Ores (answer sheet)
- T.4. Teacher's Discussion Guide: Setting up the Process
- T.5. Video Recording: The Imperial Smelting Process

(b) Pupil's Material

- P.1. List of Objectives (pupil's copy)
- P.2. How do we use Zinc?
- P.3. Extracting Zinc from its Ores (question sheet)

} White Sheets

- P.4. Data Sheets: Figure 1 Ellingham Diagram for Oxides
  Table .1 Thermodynamic properties
  Table .2 Heats of Reaction in Zn and Pb Production

} Yellow Sheets

- P.5. Summary Sheets: Uses of Zinc
  The Extraction of Zinc

} green sheets

3. Structure of the Exercise

The exercise is designed to occupy 70-80 minutes and consists of Five stages.

I A short group discussion to establish and report on some uses of zinc (5 - 10 minutes). If time is short this part of the exercise could be omitted.

II A structured exercise for each pupil to work through on his or her own, designed to establish some of the factors involved in obtaining zinc metal from its ores (20 minutes).

III A teacher-led discussion in which the information gained in II is applied to the problem of zinc production (30 minutes).

IV /

IV A showing of the video recording: The Imperial Smelting Process (10 minutes).

V Final discussion and issue of summary sheets (5 - 10 minutes).

4. Using the Package

Stage I

(i) Issue pupil sheets P1, P2, P3, and P4 (white and yellow) to each member of the group.

(ii) Briefly go through P1 with the group and then ask them to proceed to P2 which is self-explanatory. When the group have completed the work detailed on P2 they should go straight on to the work on P3. If time is short the work described on P2 could be omitted.

Stage II

Pupils should work individually on P3 . Your role is confined to assisting any pupils who encounter difficulties. (An answer sheet T.3 is provided for your use.)

Stage III

When all the pupils have completed P3 bring the group together for the structured discussion set out on T.4. It is important that you make yourself fully familiar with T.4 before carrying out the exercise.

Stage IV

Show the video recording which illustrates the Imperial Smelting Process.

Stage V

Clarify any points which pupils have not understood, before giving out pupil sheets P5 (green sheets) for retention by pupils.

T.2. OBJECTIVES (teacher's copy)

By the end of the exercise pupils should -

1. know a wide range of uses of zinc metal, its alloys, and its compounds and be able to relate these to the relevant properties
2. know and understand the relationships between standard free energy change, standard enthalpy change, standard entropy change and temperature
3. be able to interpret the data on an Ellingham diagram and apply it to metal oxide reductions
4. understand the problems involved in obtaining zinc metal from its ores, and be aware of some of the ways in which the problems can be overcome
5. appreciate the scale of operation and understand the principles involved in the Imperial Smelting Process.

In addition the exercise is designed to help pupils to -

1. learn to work co-operatively on a common problem
2. appreciate the relevance of thermodynamics to the smelting of metal ores
3. learn to work logically and apply previous knowledge to new situations
4. become more aware of the way in which chemical principles can be applied to industrial problems.

T.3. EXTRACTING ZINC FROM ITS ORES

Introduction

In the past zinc has been obtained from a variety of ores, but nowadays almost all is obtained from zinc blende which is a sulphide, ZnS. Often this zinc ore is mixed with galena, i.e. lead (II) sulphide, PbS. In this part of the exercise you will be expected to use your knowledge of thermodynamics to find out about the conditions necessary for the reduction of mixed zinc-lead ores. If you get stuck, ask your teacher to help.

You already know the relationship -

$$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

The superscript $^\circ$ tells us that the changes ΔH°, ΔG° and ΔS° refer to substances in their standard states. A standard state is defined as 1 mole of the substance at 1 atmosphere pressure and at a specified temperature. Usually the temperature at which values of ΔG°, ΔS° etc. are quoted is 298K, and hence by common usage it is assumed that if T is not specified it is 298K.

It is clear from equation 1 that ΔG° will vary according to the temperature at which the reaction is carried out. Consequently it is possible to plot the standard free energy of formation of an oxide against absolute temperature and obtain plots such as those shown in Figure 1 on the data sheets. These plots are known as Ellingham Diagrams.

Look at the plot for -

$$2CO + O_2 = 2CO_2$$

You can see that it is a straight line graph of the kind which can be represented by the general equation

$$y = mx + c$$

where m = the gradient of the plot

and c = the intercept on the y axis

Equation /

Equation (1) written in this form would read -

$$\Delta G^{\circ} = -\Delta S^{\circ} T + \Delta H^{\circ} \quad \ldots\ldots(2)$$

$$(y = m\,x + c)$$

Section A

We are now going to use the Ellingham Diagram to find out the temperature at which the reduction of zinc oxide will become thermodynamically feasible.

1. Write the equation for the reduction of zinc oxide by carbon. Assume carbon monoxide is produced.

Ans. $ZnO + C = Zn + CO$ .....(3)

2 (a) What is the standard free energy for the formation of zinc oxide at 500 K?

Ans. -595kJ

(b) What is the standard free energy for the formation of carbon monoxide at 500 K?

Ans. -310kJ

(c) Calculate ΔG° for equation (3) at 500 K.

(remember $\Delta G^{\circ} = \Delta G^{\circ}_{\text{products}} - \Delta G^{\circ}_{\text{reactants}}$)

Ans. $\Delta G^{\circ} = -310 - (-595)$

$= +285$kJ

(d) Is carbon reduction of zinc oxide thermodynamically feasible at 500 K? (Give a reason for your answer)

Ans. No because ΔG° is positive

3. Is carbon reduction of zinc oxide thermodynamically feasible at 1000 K?

Ans.... No. ΔG° is still positive.....

4. Is carbon reduction of zinc oxide thermodynamically feasible at 1500 K?

Ans..... Yes ΔG° is negative.....

5. What is the minimum temperature at which the reaction becomes thermodynamically feasible?

Ans..... 1200 K.....

It is clear from this that the reaction -

$$ZnO + C = Zn + CO$$

becomes thermodynamically feasible when the standard free energy of formation of CO becomes less than the standard free energy of formation of ZnO.

i.e. when the plots of

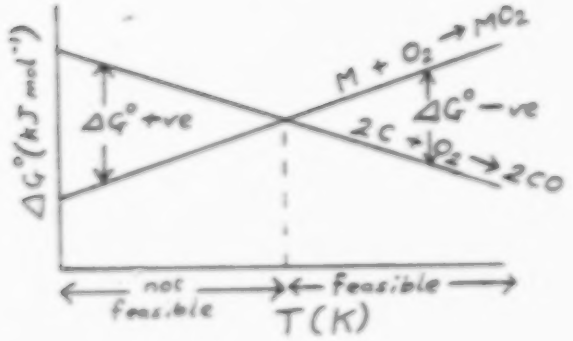
$$2Zn + O_2 = 2ZnO$$

and $$2C + O_2 = 2CO$$

intersect

Hence in general for a metal oxide reduction -

$$MO + C \longrightarrow M + CO$$



6. Write the equation for the reduction of zinc oxide by carbon monoxide.

Ans..... $ZnO + CO = Zn + CO_2$ .....(4)

7. By comparing the plots for the formation of zinc oxide and carbon dioxide work out the minimum temperature at which the reduction of zinc oxide by carbon monoxide becomes thermodynamically feasible.

Ans..... 1550 K .....

A third way in which zinc oxide can be reduced is by reaction with carbon in which the product is carbon dioxide.

8. Can you write an equation for it?

Ans..... $2ZnO + C = 2Zn + CO_2$ ..... (5)

9. At what temperature does this reaction become thermodynamically feasible?

Ans.....1300 K.....

Summary

Write out equations (3), (4) and (5) and the temperatures at which they become thermodynamically feasible.

Equation	Temperature (K)
(3)	
(4)	
(5)	

The /

The data listed above tells us about the thermodynamic feasibility of the three possible zinc oxide reductions. That is to say it tells us the temperature at which the reaction comes to a position of equilibrium in which the products are favoured. But the data tells us nothing about the rate at which equilibrium will be attained. In fact equation (4) is the main reaction involved.

10. Can you explain why this is so?

Ans.....The reaction is between a solid and a gas in.....
.....comparison with equations (3) and (5) which.....
.....are solid - solid reactions.....

We shall be considering how carbon monoxide is supplied for the reaction later in the exercise.

Now check your answers with your teacher and ask anything you are not sure about.

Section B

Smelting mixed lead-zinc concentrate

Many of the naturally occurring zinc ores also contain lead compounds. We can use the Ellingham Diagram in the same way as before to decide if it is possible to reduce mixed lead-zinc ores together.

11. Bearing in mind the importance of kinetic as well as thermodynamic considerations, write the equation for the most likely reaction for the reduction of lead (II) oxide to lead.

Ans.....$PbO + CO = Pb + CO_2$.....

12. /

12. Is this reaction thermodynamically feasible at the temperatures necessary for zinc oxide reduction?

Ans.....Yes.....

13. What do you conclude about the possibility of smelting mixed lead-zinc concentrates?

Ans....possible at temperatures for ZnO reduction.....

T.4. TEACHER'S DISCUSSION GUIDE: SETTING UP THE PROCESS

Having established some of the basic principles and facts concerning zinc production, this part of the exercise provides an opportunity for pupils to try to work co-operatively in applying the material learnt, and to produce possible solutions to some of the problems encountered. The questions below provide a suggested framework for discussion, but supplementary questions and the exploration of other aspects will depend on the response of the pupils, and teachers should not feel constrained by the questions or answers provided. It may be useful to display the overhead transparency of Ellingham Diagrams throughout the exercise.

1. Assuming that your ores contain lead and zinc sulphides how would you convert them to oxides? Write equations for the reactions.

Roast in air

$$2ZnS + 3O_2 = 2ZnO + 2SO_2$$

$$2PbS + 3O_2 = 2PbO + 2SO_2$$

2. Can you think of any problems raised by this procedure?

The question is meant to lead into a discussion of air pollution caused by the sulphur dioxide. You can discuss how the problem could be resolved and suggestions such as dissolving the gas in water or alkali might be made. The technical problems of this might be discussed and a use for the product of the reaction explored. Pupils may suggest use of sulphur dioxide for the manufacture of sulphuric acid which is in fact what is done.

3. Most of our work has concentrated on reduction of zinc ore with carbon, and carbon monoxide. Can you suggest any other methods of obtaining zinc?

There are at least two other possible methods -

(1) <u>hydrogen reduction</u>

Some of the factors you should try to bring out in discussion are:

a. the reaction is thermodynamically more favourable (see Ellingham Diagram)

b. the initial expense of producing hydrogen

c. technological problems of handling H_2/O_2 mixtures

Currently hydrogen reduction is not used.

(2) <u>electrolysis of zinc sulphate</u>

Some 60% of zinc is obtained in this way but the method requires -

a. a cheap source of electricity

b. high grade ores

The carbon reduction method is likely to become more important as energy costs rise and higher grade ores are replaced by lower grade materials.

4. Look up ΔH for the main reaction involved: the reduction of zinc oxide. What is its significance? (See data sheet.)

ΔH is positive, hence heat needs to be applied.

5. What if mixed lead-zinc ores are smelted?

No more heat is required ΔH for the PbO reduction is negative.

6. Can you suggest how carbon monoxide for reduction and heat can be supplied at the same time (see data sheet).

It is hoped that pupils will realise the possibility of a blast furnace with coke as a raw material. Hence -

$C + O_2 = CO_2 ; \Delta H^{\circ} = -394\ kJmol^{-1}$

$CO_2 + C = 2CO ; \Delta H^{\circ} = +172\ kJmol^{-1}$

You can also point out that heat is required for slag formation.

7. What is the physical state of the zinc as it is produced?

Gas

8. What is the physical state of the lead as it is produced?

Liquid

9. Sketch the furnace in which you think the process could be carried out indicating where reactants are put in and products removed. Teachers may like to get pupils to do this on an overhead transparency and compare the result with the transparency OHP1.

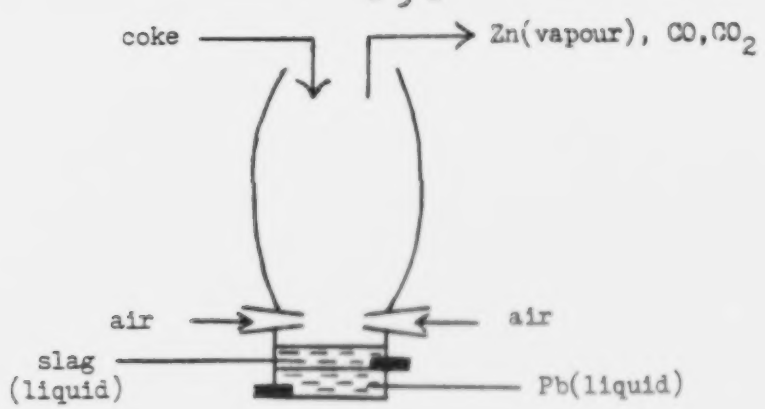


Figure 2

10. What will happen if zinc metal, produced at about 1500 K was to be cooled in the presence of carbon dioxide?

Below about 1500 K ZnO is more stable than CO_2 hence
$Zn + CO_2 = ZnO + CO$
becomesfeasible and ZnO would be reformed.

11. How might this problem be overcome?

The pupils may suggest rapid cooling. You can ask them what form the zinc would be produced in (zinc dust) and what problems this would lead to. You can discuss the problems of obtaining zinc in the form of ingots to make sheets, etc. This would involve melting and, if done in air, oxidation would occur. What would be the likely energy costs? An inert atmosphere would prevent oxidation. The problem of obtaining the zinc from the waste gases is solved in a very ingenious way in the Imperial Smelting Furnace in which the temperature of the zinc vapour is kept at about 1200 K by addition of air which reacts exothermically with carbon monoxide. The zinc vapour is condensed in a spray of molten lead, and, on cooling with water, floats on the surface of the lead and can be removed as 99.8% pure.

12. Draw a diagram of how the above might be achieved in an industrial plant.

See accompanying diagram (Figure 2).

13. /

13. Can you think of any way of further purifying the zinc?

Fractional distillation.

14. Can you suggest any use for the waste gases from the furnace?

To preheat the charge and incoming air blast.

ZINC AND YOU

Pupils Copy

P.1. OBJECTIVES (pupil's copy)

By the end of the exercise you should -

1. know a wide range of uses of zinc metal, its alloys, and compounds and be able to relate these to the relevant properties.

2. know and understand the relationship between standard free energy change, standard enthalpy change, standard entropy change and temperature.

3. be able to interpret the data on an Ellingham diagram and apply it to metal oxide reductions.

4. understand the special problems involved in obtaining zinc metal from its ores, and be aware of some of the ways in which the problems can be overcome.

5. appreciate the scale of operation and understand the principles involved in the Imperial Smelting Process.

In addition the exercise is designed to help you to -

1) learn to work co-operatively on a common problem.

2) appreciate the relevance of thermodynamics to the smelting of metal ores.

3) learn to work logically and apply previous knowledge to new situations.

4) become more aware of the way in which chemical principles can be applied to industrial problems.

P.2. HOW DO WE USE ZINC?

1. Elect a member of your group to keep a record of your findings.

2. Try to think of as many uses as you can for zinc and its compounds. Arrange your answer in the form of columns as shown below. After each one write in brackets the property or properties on which the use depends.

ZINC METAL	ZINC ALLOYS	ZINC COMPOUNDS

You should spend about ten minutes on this part of the exercise. When you have finished proceed straight to P3.

P.3. EXTRACTING ZINC FROM ITS ORES

Introduction

In the past zinc has been obtained from a variety of ores, but nowadays almost all is obtained from zinc blende which is a sulphide, ZnS. Often this zinc ore is mixed with galena, i.e. lead (11) sulphide, PbS. In this part of the exercise you will be expected to use your knowledge of thermodynamics to find out about the conditions necessary for the reduction of mixed zinc-lead ores. If you get stuck, ask your teacher to help.

You already know the relationship -

$$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

The superscript $^\circ$ tells us that the changes ΔH°, ΔG° and ΔS° refer to substances in their standard states. A standard state is defined as 1 mole of the substance at 1 atmosphere pressure and at a specified temperature. Usually the temperature at which values of ΔG°, ΔS° etc. are quoted is 298K, and hence by common usage it is assumed that if T is not specified it is 298K.

It is clear from equation 1 that ΔG° will vary according to the temperature at which the reaction is carried out. Consequently it is possible to plot the standard free energy of formation of an oxide against absolute temperature and obtain plots such as those shown in Figure 1 on the data sheets. These plots are known as Ellingham Diagrams.

Look at the plot for -

$$2CO + O_2 = 2CO_2$$

You can see that it is a straight line graph of the kind which can be represented by the general equation

$$y = mx + c$$

where m = the gradient of the plot

and c = the intercept on the y axis

Equation (1) written in this form would read -

$$\Delta G^\circ = -\Delta S^\circ T + \Delta H^\circ \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

$$(y = m x + c)$$

Section A

We are now going to use the Ellingham Diagram to find out the temperature at which the reduction of zinc oxide will become thermodynamically feasible.

1. Write the equation for the reduction of zinc oxide by carbon. Assume carbon monoxide is produced.

Ans. .....(3)

2. (a) What is the standard free energy for the formation of zinc oxide at 500 K?

Ans. .....

(b) What is the standard free energy for the formation of carbon monoxide at 500 K?

Ans. .....

(c) Calculate ΔG° for equation (3) at 500 K. (remember $\Delta G^{\circ} = \Delta G^{\circ}_{\text{products}} - \Delta G^{\circ}_{\text{reactants}}$)

Ans. .....

.....

(d) Is carbon reduction of zinc oxide thermodynamically feasible at 500 K? (Give a reason for your answer)

Ans. .....

3. Is carbon reduction of zinc oxide thermodynamically feasible at 1000 K?

Ans. .....

4. Is carbon reduction of zinc oxide thermodynamically feasible at 1500K ?

Ans. .....

5. What is the minimum temperature at which the reaction becomes thermodynamically feasible?

Ans. .....

It is clear from this that the reaction -

$$ZnO + C = Zn + CO$$

becomes thermodynamically feasible when the standard free energy of formation of CO becomes less than the standard free energy of formation of ZnO.

i.e. when the plots of

$$2Zn + O_2 = 2ZnO$$

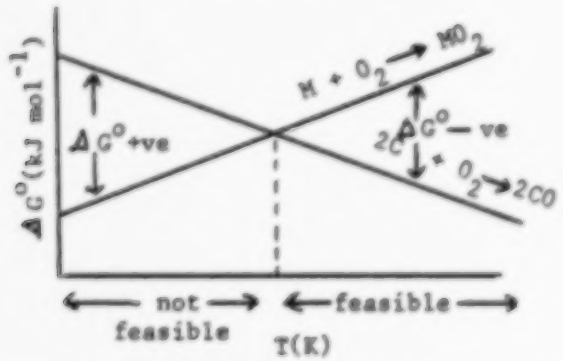
and

$$2C + O_2 = 2CO$$

intersect

Hence in general for a metal oxide reduction -

$$MO + C \longrightarrow M + CO$$



6. Write the equation for the reduction of zinc oxide by carbon monoxide.

Ans. .....(4)

7. By comparing the plots for the formation of zinc oxide and carbon dioxide work out the minimum temperature at which the reduction of zinc oxide by carbon monoxide becomes thermodynamically feasible.

Ans. .....

A third way in which zinc oxide can be reduced is by reaction with carbon in which the product is carbon dioxide.

8. Can you write an equation for it?

Ans. .....(5)

9. At what temperature does this reaction become thermodynamically feasible?

Ans. .....

Summary

Write out equations (3), (4) and (5) and the temperatures at which they become thermodynamically feasible.

Equation	Temperature (K)
(3)	
(4)	
(5)	

The data tells us about the thermodynamic feasibility of the three possible zinc oxide reductions. That is to say it tells us the temperature at which the reaction comes to a position of equilibrium in which the products are favoured. But the data tells us nothing about the rate at which equilibrium will be attained. In fact equation (4) is the main reaction involved.

10. Can you explain why this is so?

Ans. .....

.....

.....

We shall be considering how carbon monoxide is supplied for the reaction later in the exercise.

Now check your answers with your teacher and ask anything you are not sure about.

Section B

Smelting mixed lead-zinc concentrate

Many of the naturally occurring zinc ores also contain lead compounds. We can use the Ellingham Diagram in the same way as before to decide if it is possible to reduce mixed lead-zinc ores together.

11. Bearing in mind the importance of kinetic as well as thermodynamic considerations, write the equation for the most likely reaction for the reduction of lead (11) oxide to lead.

Ans. .....

12. Is this reaction thermodynamically feasible at the temperatures necessary for zinc oxide reduction?

Ans. .....

13. What do you conclude about the possibility of smelting mixed lead-zinc concentrates?

Ans. .....

P.4. DATA SHEETS

Figure 1 Ellingham Diagram for Oxides

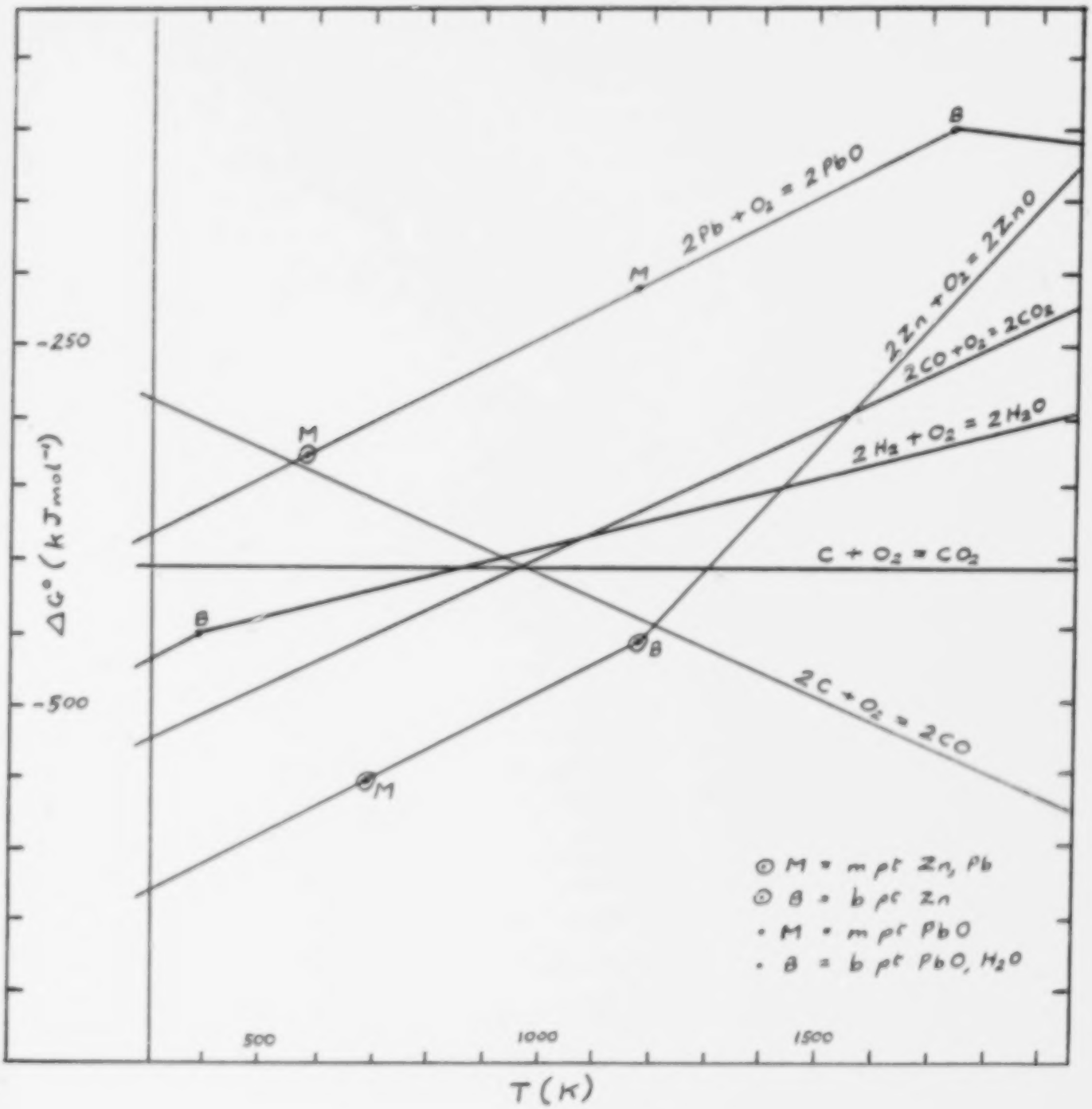


Table 1: Thermodynamic Properties

Substance	State	ΔH^o / kJ mol^{-1}	ΔG^o / kJ mol^{-1}	S^o / JK^{-1} mol^{-1}	Tm / K	ΔHm / kJ mol^{-1}	Tb / K	ΔHv / kJ mol^{-1}	$\rho(750)$ / g cm^{-3}
C	Graphite	0	0	5.7					
CO	g	-111	-137	198					
CO_2	g	-394	-395	214					
O_2	g	0	0	205					
Zn	s	0	0	41.6	692	7.36	1180	115	6.6
ZnO	s	-348	-318	43.9					
Pb	s	0	0	64.9	600	5.10	2017	176	10.5
PbO	s	-218	-188	69.4	1163	11.8	1745	215	

Data taken from Chemistry Data Book, Stark and Wallace, 1973

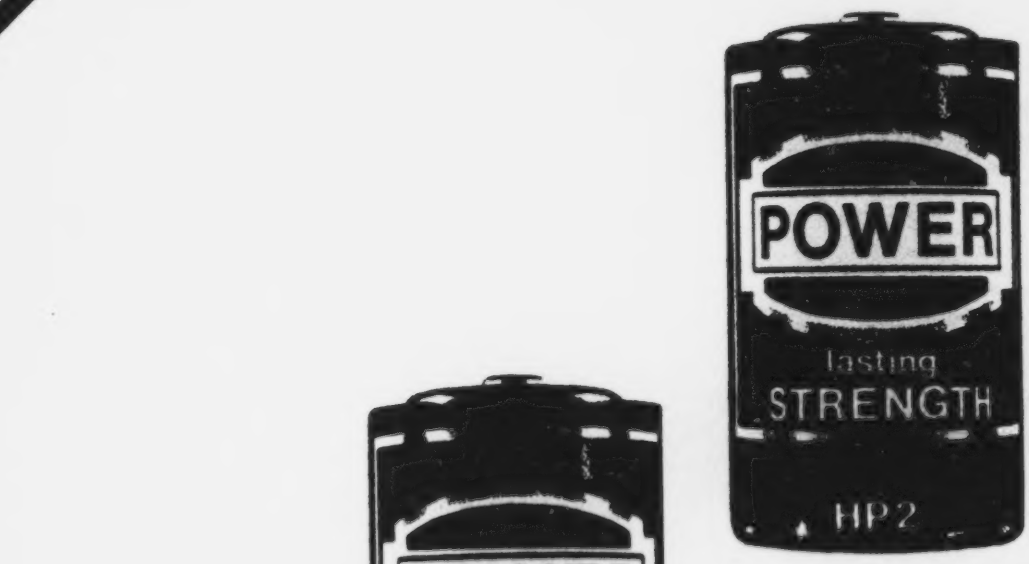
Chemical Engineers Handbook, Perry and Chilton, 1973

Metal Densities at 750 K approximate only

Table 2: Heats of Reaction in Zn and Pb Production

Process	Chemical Reaction	Heats of Reaction (ΔH) Zn or Pb kJ mol^{-1}	GJ $tonne^{-1}$	Temp K
Roasting	$ZnS(s) + {}^{3}/_{2}\ O_2 = ZnO(s) + SO_2$	-445	-6.80	1400
	$PbS(s) + {}^{3}/_{2}\ O_2 = PbO(s) + SO_2$	-418	-2.00	1000
Pyro reduction	$ZnO(s) + C(s) = Zn(g) + CO$	+355	+5.43	1200
	$ZnO(s) + CO = Zn(g) + CO_2$	+186	+2.84	1200
	$PbO(s) + C(s) = Pb(l) + CO$	+103	+0.49	1000
	$PbO(s) + CO = Pb(l) + CO_2$	-69	-0.33	1000
Electrowinning	$ZnSO_4(aq) + H_2O = Zn(s) + H_2SO_4 + \frac{1}{2}O_2$	+452	+6.91	298

Hopkin, W.; Richards, A.W. Proceedings of Symposium on the Efficient Use of Fuels in the Metallurgical Industries. Chicago Inst. of Gas Technol., 1974.



ZINC AND YOU
Summary Sheets

P.5. SUMMARY SHEETS

USES OF ZINC

1. Zinc Metal

(a) Zinc Coatings

This constitutes the largest single use of zinc. Because of its excellent resistance to most atmospheres and fresh and salt water, zinc is widely used for the protection of iron and steel. Some typical applications are given below.

Hot dip galvanising -

buckets, dustbins, car underbodies, office equipment, structures carrying overhead lines on electrified railway systems, tubular steel railings, motorway safety barriers, floodlighting towers at football grounds, transmission pylons for electricity supply, steel window frames, lamp posts, Forth Road Bridge bridge suspension cables.

Zinc spraying - see next page

Zinc spraying -

i) Protection of bridges e.g. the Severn Bridge, the Bosporus Bridge (linking Europe and Asia) and the Forth Road Bridge. Five hundred tonnes of zinc were applied to the Forth Road Bridge leading to long intervals between painting. Compare this with the continuous painting required to maintain the Forth Rail Bridge.

ii) Protection of other steel structures e.g. a fertiliser plant at Leith, a sawmill and granary at Glasgow docks; pipelines, e.g. a 1¾ mile pipeline which carries water into the hydro-electric station at Clunie in Ross and Cromarty was found to be in perfect condition after 12 years of use.

Zinc plating -

Motor car bodies, bridge suspension cables, office furniture, e.g. filing cabinets.

Sherardizing -

nuts, bolts, chains, tent pegs, screws, washers, hinges, springs, scaffolding connectors.

Zinc dust paints -

prefabricated sections of ships, off-shore oil installations, steel structures of buildings (7000 tonnes of steelwork used in the construction of the National Exhibition Centre in Birmingham were treated in this way).

(b) Sheet and Strip

dry batteries
plates used in printing for photoengraving and lithographs
zinc sheet used in building for roofing, cladding, gutters, rainwater pipes.

(c) Zinc Dust

In the manufacture of zinc and sodium hydrosulphites (ZnS_2O_4, $Na_2S_2O_4$) used as bleaches (for textiles and for woodpulp in paper making). This is by far the most important use.
gold refining
electrolytic zinc refining

2. Zinc Alloys

(a) Die Casting

Die casting is a process in which molten alloy is forced under pressure into a steel die made in two or more parts to permit removal of the castings. Runs of many thousands of identical castings can be made in this way. The most common zinc die casting alloy contains 4% aluminium and 0.04% magnesium; a slightly /

slightly harder alloy is obtained by including 1% copper. Among the articles produced in this way are:

(i) in the car - carburettors, fuel pumps, body trim, brake pistons, radiator grill

(ii) in the home - washing machine pumps, refrigerator pumps (the alloy is not attacked by Freons), locks, door handles, taps, lawnmowers, tape recorders, record players, cameras, radios, scale model cars, etc.

(iii) in the office - duplicating machines (over 90 die castings are usual in one machine), typewriters.

(b) Brass

Brass is an alloy of copper and zinc. The proportions of zinc can vary from 20-45%. Among the uses of brass are:

plumbing, electrical fittings, e.g. in light fittings and electric plugs, decorative ware.

3. Zinc Compounds

(a) Zinc Oxide - a white pigment used in paints, where it imparts toughness to the paint film, prevents yellowing and resists mildew growth.
rubber where it accelerates vulcanisation and strengthens the rubber. Car tyres can contain up to 5% zinc oxide.
cosmetics
match heads
ceramic glazing
photocopying paper
As a result of the increased life of radial tyres, and the fact that smaller cars (and hence smaller tyres) now dominate the market, demand for zinc oxide is falling.

(b) Lithopone - This is a mixture of zinc sulphide and barium sulphate (both white pigments). Lithopone is used in distempers and paints, in the manufacture of linoleum, paper and opaque plastics.

THE EXTRACTION OF ZINC

In this exercise you have been applying thermodynamic principles to the problem of smelting mixed zinc and lead ores. Your answers to Part II provide a record of that part of the exercise. This summary is mainly concerned with the Imperial Smelting Process.

Most zinc is now obtained from sulphide materials which also contain lead (and often silver) or copper. The most common of these ores is zinc blende, one form of which is called sphalerite. The first stage after the ore has been mined is to separate out the unwanted rock material (gangue) to produce 'concentrates' which are rich in zinc and lead containing material. This is most usually done by a flotation process in which the finely crushed ore is agitated with water, containing certain chemicals. The gangue is easily wetted and even though it is lighter than the ore, it sinks to the bottom. The finely crushed ore is held in the froth which forms on the surface and therefore can easily be skimmed off.

The concentrates are then roasted in air to convert them to oxides.

$$2\,ZnS + 3O_2 = 2ZnO + 2SO_2$$

$$2PbS + 3O_2 = 2PbO + 2SO_2$$

The sulphur dioxide produced is used to manufacture sulphuric acid. From this stage there are two main routes to production of zinc metal.

1. Electrolysis

The zinc oxide is dissolved in dilute sulphuric acid to produce zinc sulphate solution which after purification can be electrolysed to yield zinc at the cathode.

2. Thermal Smelting

Carbon is used to reduce the zinc oxide. Currently more than half of the world's zinc is produced by electrolytic methods and all zinc produced in the U.S.A. is made in this way, but thermal smelting is becoming more important as energy costs rise and more lower grade ores need to be used.

In the Imperial Smelting Process (see Figure 2) roasted concentrates are mixed with coke and fed into a blast furnace. Pre-heated air entering the base of the furnace reacts with the coke as follows:

$$C + O_2 = CO_2 \; ; \; \Delta H^\circ = -394 \text{ kJ mol}^{-1}$$

$$CO_2 + C = 2CO \; ; \; \Delta H^\circ = +172 \text{ kJ mol}^{-1}$$

Since the overall reaction is <u>exothermic</u> heat is supplied for the reduction of the zinc oxide by the carbon monoxide produced which is <u>endothermic</u>.

$$ZnO + CO = Zn + CO_2 \; ; \; \Delta H^\circ = +65 \text{ kJ mol}^{-1}$$

The Ellingham Diagram indicates that reaction between zinc oxide and carbon is thermodynamically feasible at a lower temperature than that required for the reaction between zinc oxide and carbon monoxide. In fact the rate of attainment of equilibrium for a solid-solid reaction of this kind is so slow that we can ignore this reaction. Furthermore, we have concluded from the Ellingham Diagram that a temperature of 1550 K is necessary for the reaction between zinc oxide and carbon monoxide to become thermodynamically feasible. In practice the process operates at about 1400 K, the reason being that the substances taking part in the reaction are not in their <u>standard states</u> and hence a negative free energy change for the reaction is possible at a somewhat lower temperature than that predicted by the Ellingham Diagram.

However, the zinc produced at 1400 K is still in the form of a vapour (B. Pt. Zn = 1180 K). If lead (II) oxide is present in the ore this too will be reduced at the operating temperature of the furnace.

$$PbO + CO = Pb + CO_2$$

However, the lead will be produced as a liquid (B. Pt. Pb = 2017 K; M. Pt. Pb = 600 K). The lead and molten slag produced collect at the bottom of the furnace and can be run off (see Figure 2).

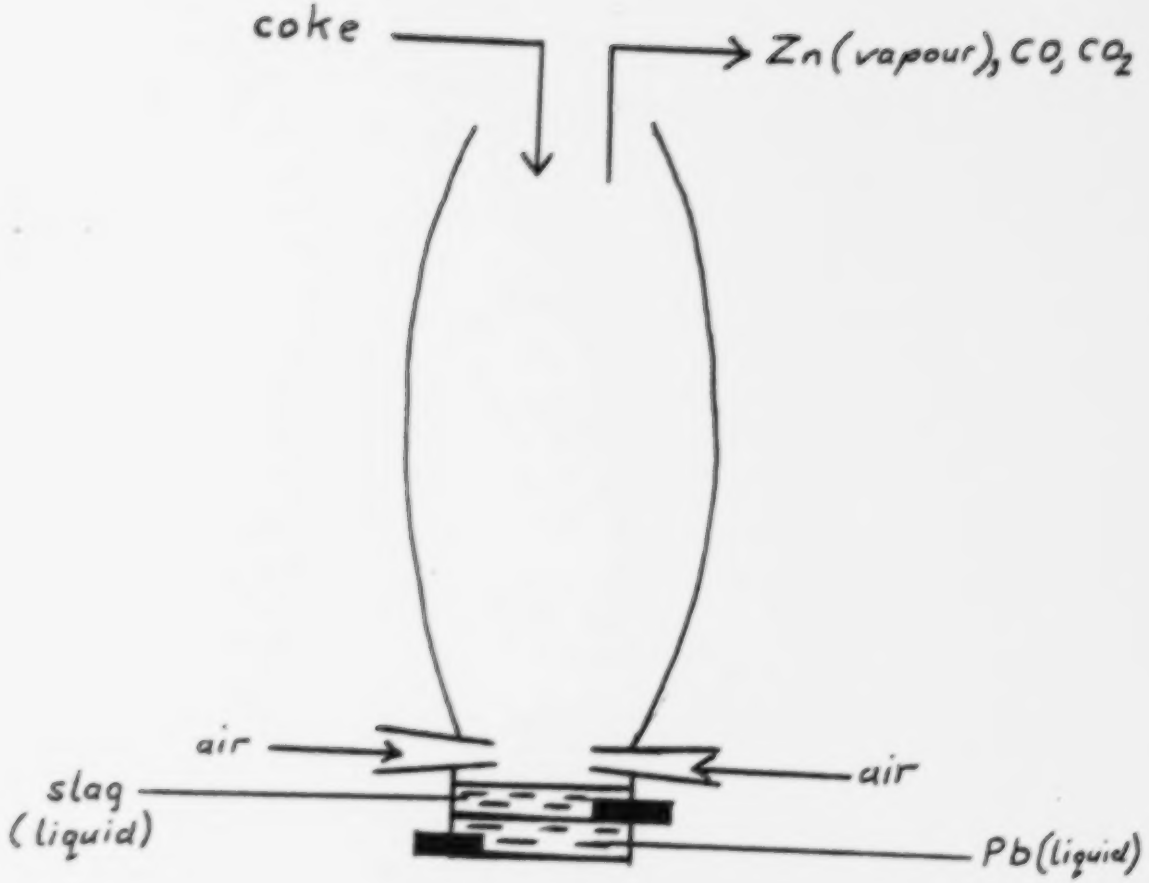
The zinc vapour, together with a gas mixture containing carbon monoxide, carbon dioxide and nitrogen passes out from the furnace. If it were to be cooled the reaction

$$Zn + CO_2 = ZnO + CO$$

which /

which is the reverse of the reaction used to produce the zinc, would become thermodynamically feasible, and hence the zinc would be re-oxidised. Rapid cooling would prevent this reaction proceeding to any significant extent, but the zinc would be produced in the form of zinc dust. This would then need to be remelted in an inert atmosphere (to prevent re-oxidation), if metal suitable for rolling, casting, etc. is to be obtained. The problem is solved in the Imperial Smelting Process. The zinc vapour is rapidly condensed in a spray of molten lead. The lead, which now contains about 2.4% dissolved zinc passes first through water cooled channels where it is cooled to 675 K and at this temperature the zinc comes out of solution. Molten zinc of 98.8% purity can then be run off. The lead, still containing 2.1% zinc is recirculated. If further purification of the zinc is necessary (e.g. in making die-casting alloy) the zinc can be further refined to a purity of 99.99% by fractional distillation.

Currently there are 13 I.S.P. furnaces in operation throughout the world. In 1980 they produced 730,000 tonnes of zinc and 330,000 tonnes of lead.


coke
Zn (vapour), CO, CO_2
air
air
slag
(liquid)
Pb (liquid)

PRODUCTION TEAM

Maisie Clubb
Kirsty Letton
Lorraine Logan
Alan Johnstone
Douglas McConnach

BEST COPY AVAILABLE

Units in the series

TO MARKET A DRUG

NITROGEN FOR THE NINETIES

ZINC AND YOU

TITANIUM The aerospace metal

ORGANIC LIQUIDS CONTAINING OXYGEN

THE VINYL CHLORIDE PROBLEM

Further copies of these units
are available from the

Scottish Council for Educational Technology
Victoria Crescent Road
Dowanhill
Glasgow G12

BEST COPY AVAILABLE